EXPERIMENTAL STUDIES OF COLLECTIVE PROPERTIES OF SOME RADIOACTIVE NUCLEI

AND

A DETERMINATION OF THE HELICITY OF NEUTRINOS

BY

INGVAR MARKLUND

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ALMQVIST & WIKSELLS BOKTRYCKERI AB

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INAUGURAL DISSERTATION

BY

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To BARBRO

Experimental Studies of Collective Properties of Some Radioactive Nuclei

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The experimental data of radioactive nuclei support a description of the nucleus as a shell structure, which can perform oscillations in shape and size. Some nuclear properties are thus caused by the nucleons collectively and others by a single particle in the nucleus. The first part of the present thesis reports on some experimental studies of these nuclear properties with preference for the collective ones.

In 1957 Lee and Yang presented the hypothesis of non-conservation of parity in weak interaction. Their two-component theory of the neutrino implies that the parity is not conserved in interactions involving the neutrino. As this invariance law is assumed to be valid in earlier theories, it became of the greatest importance to make thorough tests of the predictions by Lee and Yang; hence, the second part of this thesis contains a description of such a test by determining the helicity of neutrinos.

The experiments are described in the following papers:

I. Torsten Lindqvist and Ingvar Marklund, The Influence of l-forbiddenness on Magnetic Dipole Transitions in Tl^{203}. *Nuclear Physics 3* (1957) 367.

II. Torsten Lindqvist and Ingvar Marklund, Mixing Ratios of $2+ \rightarrow 2+$ Transitions in Some Even Nuclei. *Nuclear Physics 4* (1957) 189.

III. O. Nathan and I. Marklund, Rotational Character of the Transition from the 473 keV Level in Tm^{169}. *Nuclear Physics 6* (1958) 102.

IV. G. Bäckström and I. Marklund, The Decay of As^{76} to Se^{76}. *Arkiv för Fysik 17* (1960) 393.

V. Z. Grabowski, S. Gustafsson and I. Marklund, Angular Correlation Measurements on Levels in Se^{76} and Fe^{56}. *Arkiv för Fysik 17* (1960) 411.

VI. Ingvar Marklund, Decay of Eu^{152m}. *Nuclear Physics 9* (1958/59) 83.

VII. I. Marklund, O. Nathan and O. B. Nielsen, $0+$ states of Sm^{152} and Gd^{152}. *Nuclear Physics 15* (1960) 199.

VIII. Ingvar Marklund, Bob van Nooijen and Zbigniew Grabowski, $0+$ levels of Even Nuclei in the Rare-earth Region. *Nuclear Physics 15* (1960) 533.

IX. Ingvar Marklund and Lorne A. Page, On the Helicity of Neutrinos, *Nuclear Physics 9* (1958/59) 88.

According to the one-particle shell model $M1$ transitions are forbidden, if the change in orbital angular momentum l is more than one unit (l-forbidden transitions). The experiment described in paper I gave a factor of 1.3×10^{-3} for the retardation of the l-forbidden $M1$ transition in Tl^{103} compared to the l-allowed one. This nucleus has a single proton hole in the closed shell of 82 protons and is thus well fitted for the shell model description.

Paper II describes an angular correlation study of the mixing ratios of the transitions between the second and first 2+ level in some even nuclei. On the basis of the collective model these levels were expected to decay by pure $E2$ radiation. The experimental results show strong $E2$ transitions but also measurable competing $M1$ transitions.

In paper III we report a half-life determination of the 473 keV level in Tm^{169}. The half-life was found to be less than that of the neighbouring single particle levels. Thus the earlier value is incorrect, and the level could be reinterpreted as a rotational state on the 379 keV single particle level, in good agreement with the predictions of Mottelson and Nilsson.

Papers IV and V contain the results of an investigation of the As^{76} decay, performed with a double focusing spectrometer and a scintillation apparatus. A quantitative analysis of the scintillation coincidence spectra gave relative branching ratios. The spins of the new levels were determined by angular correlation measurements. The three lowest excited levels may be interpreted as one, two and three phonon excitations, respectively, and the highest observed level is probably of octupole character.

Paper V also describes an angular correlation measurement of the decay of Co^{56}. Our spin assignment for the 4.10 MeV level is unique, but it is in discrepancy with the earlier reported values.

In papers VI and VII we report two investigations of the decay of Eu^{152m}. This nucleus is one of the few sources, suitable for a neutrino helicity experiment. (Paper IX.) Thus we found it worth while to check its decay by a high resolution beta spectrometer and by a coincidence apparatus. The decay of Eu^{152m} is also of particular interest, as one can study the spectrum of a spherical nucleus ($_{64}Gd_{88}^{152}$) and that of a strongly deformed nucleus ($_{62}Sm_{90}^{152}$) at the same time. Thus, important information can be gained about the mutual relationship between the collective modes of excitation in the two different types of nuclei.

In papers VII and VIII we present the results from a search for excited 0+ levels of even nuclei in the rare-earth region. We found seven 0+ levels by measuring angular distributions and conversion coefficients. The calculations by Rainer of the branching ratios from excited 0+ levels are in agreement with our experimental result for the spherical nucleus Gd^{152}, but they differ by a factor of ten from that found for the deformed nucleus Sm^{152}. Thus, refined calculations are needed. The strength of the rotational-vibrational coupling is experimentally found to be two to four times weaker than that given by the strong coupling model in the hydrodynamical approx-

imation. The experimental trend of levels of even nuclei with $A = 50$–250 is discussed, and a number of new spin assignments are proposed.

Paper VII also includes an application and an extension of the method by Hultberg to determine relative gamma ray intensities accurately. The angular correlation coefficients A_2 and A_4 are given in paper VIII as a function of the multipole mixing parameter δ for some common spin sequences.

Paper IX deals with an experiment to determine the helicity of neutrinos emitted in the orbital electron capture decay of Eu^{152m} to Sm^{152}. When a neutrino and a gamma ray were emitted in opposite directions, nuclear resonance fluorescence might occur in our Sm_2O_3 scatterer. Before the gamma ray was scattered, it had passed through a transmission Compton analyzer for circular polarization. The observed resonance fluorescence intensity *did* change with the direction of the magnetic field in the analyzer. The sign and magnitude of the polarization of the detected gamma rays were measured. The neutrino emitted in this orbital electron capture was concluded to have negative helicity, that is, the spin and momentum of the neutrino together define the sense of rotation of a left-handed screw. The two-component theory of Lee and Yang thus is valid.

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